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ABSTRACT

The eonomic iron deposits of El Bahariya Oasis are confined to Karst features, and it is suggested here that they were formed through lateritization processes during the senile stage of Post-Eocene Karst event. Karst depressions and excavated unconformity acted as traps where iron ores accumulated. Iron deposits together with soil products also form surficial crust (duricrust), capping and cementing highly subdued and altered carbonate rocks. Pyrite framboids, siderite, goethite, hematite, manganese oxides and barite are the essential minerals constituting the ores. These minerals together with clays, ochers and different morphologic forms of fresh water calcite and silica exhibit the following main megascopic and microscopic fabrics:1) crustified structure; 2) cockade structure: 3) rhythmic banding and lamination; 4) large scale concretions and algal pisolites; 5) cement of degraded allochems and autochthonous fragments; 6) filling of fossil cavities and; 7) preserved microcellular structures and tissues of plant remains. These fabrics denote depositional and lithification processes from weathering solutions, with direct or indirect organic influences, rather than replacement processes by unknown solutions coming from unknown sources. The evolution of the megascopic and microscopic ore fabrics, the oxidation of the iron bearing minerals and their relations with the gangue and weathering products reflect the changes in the moisture regimes and the physicochemical conditions, involved during the pedogenesis.

1. INTRODUCTION

The main exploitable iron ore deposits of Egypt occur in three localities, distributed within the conekarst terrain of the northeastern plateau of El Bahariya depression, particularly restricted to a narrow zone along the main scarp of this depression (Fig. 1). Theories proposed for ore genesis are contradictory, among the main; syngenetic-supergene; syngenetic-hypogene; epigenetic-supergene and epigenetic-hypogene theories. Multigenetic combinations of two or more of these modes were also proposed (Table 1). Most of available publications deal with individual occurrences, with emphasis on descriptive geology and estimates of ore reserves. The controlling parameters responsible for the ore formation, on local and regional scales were given no or little attention. Detailed studies on local and economic geology-mineralogy appear in the publications of El Akkad and Issawi 1963; Said and Issawi 1964; Basta and Amer 1969 a, b, c, d; Osman 1969; Kamel 1971; El Sharkawi et al. 1984 and Khalil 1984.

The aim of this work is to present systematic and new observations on the nature of these iron deposits, including: 1) their regional and local distribution; 2) geologic, geomorphologic and stratigraphic setting; 3) geometric and textural characteristics; 4) the paragenetic association; 5) genetic types and mode of formation; and 6) factors and processes involved in their genesis. To achieve this, detailed field observations are given for each ore locality. Isometric, geologic and geomorphologic maps and representative lateral and vertical profiles are constructed. Megascopic and microscopic descriptions of ores and associated materials are presented. The formation of the ores in association with karst, involving deep weathering, sedimentary, pedogenic and diagenetic

processes is indicated. The recognition of ore controlling parameters and its mode of genesis are important prerequisites for future exploration of new similar occurrences.

2. GEOLOGICAL ASPECTS AND CLASSIFICATION OF THE ORE DEPOSITS

The northeastern part of El Bahariya depression is covered mainly by the Early Cenomanian Bahariya Formation, followed unconformably by Eocene carbonates. The Bahariya Formation is distributed along the main scarp of the depression and constitutes the lower part of Gabal Ghorabi. It consists mainly of fluviodeltaic sediments, intercalated towards its upper part by marker horizons of ironstones. The Eocene carbonates build up the plateau and include the following formations:

Table 1. Previous Theories Of The Origin Of El Bahariya Iron Ore Deposits

I Syngentic	II Epigenetic
I a: Supergene.	**II a: Supergene.**
The ore deposits have been formed contemporaneously with the Eocene limestones by surface marine or fresh water in either shallow marine or lagoonal lacustrine environments during the deposition or by diagenetic replacement processes. The source of the iron is of erosional, thus of supergene origin, e. g.:	The re deposits have been formed later than the Eocene limestones by supergene solution. The suggested environment of deposition is shallow water lacustrine. The ore matter was introduced by the leaching of the adjacent sedimentary beds, e.g.:
EL AKKAD and ISSAWI (1963) SAID and ISSAWI (1964) OSMAN (2969) KAMEL (1971)	BALL and BEADNELL (1903) HUME (1909) ATTIA (1950) EL SHAZLY (1962) Tosson and SAAD (1974). EL SHARKAWI and KHALIL (1977) KHALIL (1984) El SHARKAWI et. al (1984).
I b: Hypogene.	**II b: Hypogene.**
The ore deposits have been formed contemporaneously with the Eocene limestones. The ore matter is of hypogene — hydrothermal origin and accumulated by replacement processes during the diogenesis of the host rocks in either lacustrine or morine environments, e.g.:	The ore deposit is of later origin than the Eocene carbonates. The ore minerals have been formed during replacement by gydrothermal soultion rose from unknown depth with or without relations with volcanic activities, e.g.:
EL SHAZLY (1959) AWAD et. al (1980) Agthe (1985)	GHEITH (1955 and 1959) Nakhla (1961) AMER (1968 and 1973) BASTA and AMER (1969 b,c&d) OSMAN (1969) KAMEL (1971). TOSSON and SAAD (1974) AWAD et. al (1980) EL SHARKAWI et. al (1984)

Other possibilities of multigenetic combinations of two or more of these modes of origin are also proposed, e.g.:

II a + II b : TOSSON and SAAD (1974) and EL SHARKAWI et. al (1984)

I b + II b : AWAD et. al (1980).

I a + II b : KAMEL (1971).

formation	age	lithology
El Hamra	Late Middle to Late Eocene	fossiliferous limestones, sandy and glauconitic with intercalations of clays and sandstones.
Qazzun	Late Middle Eocene	Spheroidaly weathered, white, silicified limestones and dolostones.
Naqb	Early Middle Eocene	Pink to violet, brecciated, caverneous, silicified limestones, dolostones and dedolomite.

Traces of highly weathered basalt (Oligocene-Miocene!?) occur at Qaret El Bahr, east of El Gidida mine, yet no thermal effects related to these volcanic rocks are observed. The residual landforms of this area are covered by playa deposits, alluvial sediments and sand dunes of Quaternary age.

The area of El Bahariya Oasis is a structurally high feature, developed along the stable-unstable shelf contact of Said (1962) or the Pelusium Line of Neev (1975 and 1977). It forms a part of the major swell system, extending from Farafra Oasis to Abu Roash area, near Cairo. The main structural elements of this area are NE and E-W trending folds and NE, NW, E-W and N-S faults, generated and rejuvinated during six tectonic phases (El Akkad and Issawi 1963; Amer 1973; and Lotfy 1988). The echo of collision between the adjacent Central and Northwest African Plates along the Pelusium Line is the most probable mechanism, responsible for the evolution of the main structural elements of this area (Lotfy 1988).

The uplifted Eocene rocks of the plateau bave been subjected to intensive deep weathering processes under humid to subhumid tropical paleoclimate, resulting in the formation of typical cone and cockpit karst landforms, associated with surface and subsurface solution openings and karst products (El Aref et al. 1987). Tbe general karst landscape is interrupted by three large scale depressions; Ghorabi-Nasser; El Harra and El Gidida. The karst products are displayed by "terra-rossa", silcrete, ferricrete and calcrete duricrusts and intra-karstic calstic, cbemical and biogenic sediments. The karst was mainly generated during the humid to subhumid climate of the Oligocene-Early Miocene (?) and most probably modified or even rejuvenated during the rainy periods of the Holocene. As a result of the karstification, the original marine composition and textures of the karstified Eocene rocks were obliterated. Spheroidal weathering and formation of corestones, dissolution, brecciation, diffusion processes and formation of "Liesegang" rings, dedolomitization, silicification, concentration of Fe and Mn oxides and hydroxides, late calcite cementation and deposition of evaporitic minerals are the main diagenetic processes related to the vadose and phreatic conditions of the karst environment (El Aref et al. 1987 and Lotfy 1988). The dedolomitization has played a significant role in the alteration of the dolostone facies of the Naqb Formation (consisting mainly of ferroan dolomite), consequently to the production of rusty crusts, rottenstone and "terra-rossa", which are responsible for the pink to violet colouration of this formation.

The studied iron deposits are found to be confined to karst features and can be classified into the following genetic types:

1. Filling iron type and iron duricrust of Ghorabi-Nasser area
   a) Filling iron type of excavated unconformity (Naqb Ghorabi)
   b) Iron duricrust (Gabal Ghorabi)
   c) Filling ore type of intermontane basin (Nasser locality).
2. Strata-bound to stratiform iron oxide or hydroxide confined to lake sediments (El Harra locality).

3. Filling ore type of large scale depression (El Gidida mine).

3. DESCRIPTIONS OF THE IRON OCCURRENCES

3.1. The Iron Ore Deposits Of Ghorabi-Nasser Area

As shown in Figure 2, Ghorabi-Nasser area represents a semicircular, large depression, surrounded by the karstified rocks of the plateau and connected southwestwards to the main depression of El Bahariya. It could be considered as a doline form that resulted during the retreat of the main scarp, by the denudation of the crest and limbs of Ghorabi anticline, trending NE and plunging to the N. The core of this depression is occupied by a group of discrete inselbergs of Gabal Ghorabi, rising abruptly from the surrounding low land. This may indicate intense excavation along the flanks of the anticline, leaving the inselbergs as relicts.

An elongate intermontane basin or karst marginal plain (Jakus 1977), about 400 m wide and 3.5 km long, is developed at the northern part of the depression. It is bounded to the N by karst cones and to the S by an uprised elongate ridge. This basin is initially of tectonic origin, as it represents a graben developed between two parallel E-W faults. (Fig. 2). Towards the doline, the karstified carbonates show a remarkable reduction in thickness and become highly peneplained. They form stepped karst escarpments, diminshing gradually towards the depression, with peneplained surfaces, dominated by morphogenetic karren solution features. Naqb Ghorabi is a narrow wadi, cutting across the plateau and slopes gently in the direction of the depression.

3.1.1. Filling iron type of excavated unconformity surface (Naqb Ghorabi)

The Bahariya Formation and the karstified carbonates of the Naqb Formation constitute the rocks cropping out in this locality. These formations are separated by a surface of unconformity, up to 4 m in thickness, (Pl. I, Fig. a). The Eocene carbonates are highly affected by dissolution, brecciation, silicification and dedolomitization processes, the effect of which increase gradually towards the unconformity and the exposed surfaces. The crests of the karst cones of these rocks are mantled by silcrete, whereas the cone hill slopes and the surrounding peneplained surface are covered by "terra-rossa". The surface of the unconformity is filled mainly with variable proportions of collapse breccia fragments, together with residual sediments, chemical and organic products (Pl. I, Fig. a). The breccia fragments are derived mostly from the Naqb Formation and appear to be associated with bedding, controlled sag fissures, passing through crackle breccia into network solution fissures and cracks in the overlaying carbonate rocks. This indicates karst activity along the weak plane of the unconformity, coniciding with the relatively impermeable beds underlying it. The collapse fragments are either encrusted by crustified iron minerals (botryoidal goethite and hematite), calcite and quartz, or embedded in partially consolidated ocherous sediments rich in fine intraclasts, skeletal fragments and organic remains (algal oncolites and cellular plant debris). The algal oncolites consist of concentric laminae of iron stained micrite growing around soft rotten material or even without any preceptible nucleus. The interior parts of the oncolites and the cell walls, intercellular and intracellular spaces of the plant remains are partially replaced by oxidized minute pyrite crystals, pyrite framboids, and siderite (Pl. 1, Figs. b,c and d). The ferruginated allochems are usually cemented by crustified goethite and/or hematite, followed by mosaic calcite and quartz. Orthosparitic calcite showing idiomorphic termination towards the pore spaces or forming crustified layers of calcrete type are commonly developed above the external surfaces of the megascopic iron crusts. The remaining space left behind these calcite forms may be filled with quartz, length slow chalcedony, gypsum and anhydrite.

3.1.2. Deep weathering profile (duricrust profile) of Ghorabi inselbergs

This profile forms a distinctive morphogenetic marker capping the summits of the residual inselbergs of Gabal Ghorabi and the surrounding scarp (Fig. 2). It attains up to 13 m above the large inselbergs and is much reduced or generally missing above smaller ones. It occurs directly above the Bahariya Formation, suggesting that the denudation in this locality extended down until the Cretaceous-Eocene unconformity.

Two main horizons are recognized in this profile, an upper indurated horizon, overlaying highly subdued and altered rocks (Fig. 3). The latter, 9 m thick, consists along its upper part of destructed and buried pavements, embedded in ocherous clayey sediments or encrusted by crustified iron oxides. These materials pass downward into highly altered limestones, diversified by karst solution features of different forms and diameters. The incipient stage of dissolution shows solutuion joints of network pattern and small cavities. Progressive widening of the solution joints led to the formation of vertical and inclined large scale solution channels and caves, filled with soil products and iron ore. These solution forms appear to be developed during surface water infilteration into vertical and inclined joints, connected with lateral subsurface passages or openings. Gradual detachment of the weathered limestones forms collapse breccia, which may sink down into softer ocherous kaolinitic sediments inside the solution forms. Degradation of the large scale soultion features, resulting in the formation of large breccia bodies is commonly observed. The intact rocks include highly silicified and ferruginated limestones composed of ferruginated skeletal fragments and pelloids, cemented by cryptocrystalline to microcrystalline quartz aggregates. The quartz cement includes numerous red stained filaments, probably of organic origin. Towards the intervening solution channels and caves, the intact rocks become crackled and brecciated and change gradually into earthy masses of rottenstone. These form selvages along the walls of the solution features or concentric zones around large scale collapse breccia fragments, indicating that the alteration was brought about by circulating water (Pl. I, Fig. e). The infilling karst products include: 1) collapse breccia; 2) lenses of red kaolininic shale, ochers, black muddy materials, siltstone and sandstone. These are of variable thicknesses and lengths, but generally of horizontal attitude. The shales and ochers grade laterally and vertically into iron pisolites or oxidized algal oncolites (Pl. I, Fig. f): 3) oxidized plant tissues and stromatactis algal filaments (Pl. I, Figs. g and h); 4) small nodules and irregular clots of oxidized pyrite framboids or siderite (Pl. I, Fig. i) and, 5) concentric spheroids of botryoidal goethite, hematite or pyrolusite (Pl. II. Fig. a). The cement of these materials consists of cryptocrystalline quartz aggregates, crustified calcite and crustified iron oxides with or without idiomorphic barite crystals and gypsum. The crustified iron oxides are the most predominant type of cement, being composed of rhythmic alternation of yellow soft and brown hard layers, up to 10 cm in thickness. The yellow layers consist of ochers and kaolinite with oxidized pyrite framboids, siderite and detritus silty quartz grains. The hard brown layers are made up of successive crusts of colloform goethite and hematite with or without manganese oxides or hydroxides. These rhythmic layers are commonly developed around collapse breccia, forming cockade structure or along the walls of the solution forms (Pl. II. Fig. b). They may form continuous irregular and folded bands of different thicknesses within the available large scale solution channels or cavities.

The indurated upper horizon consists of successive thin layers of different compositions and textures (Fig. 3), terminated by quartzite or crustified layers of chert (silcrete). It forms a hard cap, up to 2 m thick, at the tops of the high and large inselbergs, preserving the underlying weathered rocks. In some places, this horizon is generally missing or is only represented by accumulation of rubbles mixed with detrital fragments of crustified iron oxides, calcrete, chert and barite. The con-

tact between the upper and lower horizons of the weathering profile is gradational. It is manifested by disintegrated carbonate fragments, encrusted by sesquioxides of iron and manganese with clay, passing upwards into crustified banded ore with discrete iron concretions and nodules of calcrete (Pl. II, Fig. c). Light laminae consisting of barite, chalcedony and blocky calcite are intercalated with the iron bands. Barite crystals grow progressively on the outer surfaces of earlier iron bands and exhibit idiomorphic termination towards the succeeding bands. The remaining space between the idiotopic barite crystal is usually filled with blocky calcite. Calcite may also form stalactites, growing within the available empty space between the iron bands, or successive concentric layers of calcrete type, cementing fragments of crustified ore or iron concretions (Pl. II, Figs. d and e). Pyrite framboids are frequently distributed within the iron rich bands and represent the main cement of the subsequent layers, i.e., the iron pisolites, barite breccia, laminated sandstone and earthy materials (Pl. II, Fig. f). Plant remains are also enclosed within the sediments of this horizon.

3.1.3. Filling ore type of intermontane basin (Nasser locality)

The iron deposits of Nasser locality are confined to the intermontane basin (Karst marginal plain) or form ferricrete duricrust covering the uprised elongate ridge (Fig. 2). The ore is of lenticular form with variable thicknesses, ranging from 1 to 25m. It's lower surface is extremely irregular and extends down to the clastic rocks of the Bahariya Formation, where isolated masses of this formation are enclosed within the ore. Block, boulder and pebble sized Eocene carbonate fragments are also embedded within the ore. The ore exhibits well developed banded and laminated structure, consisting of rhythmically alternating yellow and dark brown bands, ranging in thickness from 1 to 12 cm. The bands are generally regular, mostly with well defined contacts or are occasionally deformed, forming contorted or twisted layered structure, overturned and folded bedding. They may be symmetrically deposited all-around altered limestone fragments or rotten materials (Pl. II, Fig. g). The individual bands may consist of successive thin laminae of different shades of yellow or brown. The yellow bands or laminae consist of ocherous materials, whereas the dark bands are made up of oxidized framboidal pyrite, minute pyrite crystals and siderite, together with quartz grains of silt size. The cement of these constituents is colloform goethite with or without hematite. Younger generation or reniform goethie and/or stalactiforms or dendrites of manganese oxides are frequently deposited within spaces between the convoluted rhythmic bands. Irregular masses or small lenticles of yellow ochers and iron pisolites are also embedded within the banded ore. The ore and the associated ochers are highly intersected by veinlets of calcite, gypsum and halite.

3.2. Strata-Bound To Stratiform Iron Oxide And Hydroxide Confined To Lake Sediments (El Harra Locality).

El Harra area is covered by clastic rocks and associated ironstones of the Bahariya Formation, karstified rocks of theNaqb Formation, lake sediments and Quaternary deposits (Fig. 4). It is traversed by a major asymmetrical plunging anticline, trending NE-SW and sets of NE-SW, NW-SE and E-W trending faults, resulting in the formation of dislocated fault blocks along the main scarp of El Bahariya depression. The deposit at Wadi El Harra, consists of an oval outcrop of lake sediments, resting unconformably on the ironstones of the Bahariya Formation (Pl. II, Fig. h). These sediments fill a depression up to 15 km^2, developed along the western flank of the anticline, and bound to the N and NE by degraded karst cones with stepped escarpments and to the S and W by the fault blocks of the main scarp (Figs. 5 and 6). The lake sediments attain up to 15m thick

along Wadi El Harra. Marginwards the thickness of these sediments is highly reduced (Fig. 6). Two main successive sedimentary sequences are observed in the lake deposits (Fig. 7). The contact between them is usually irregular, and marked by scour and fill structure with prominent gravel filled channels. The different sedimentary facies of the lake sediments show wedging and intertonguing relationships, especially towards the lake margins. The lithofacies associations of the lower sequence are interpreted as basin plain sediments, as they are *predominantly composed of coarsing upward bed-load clastics mixed with suspended sediments.* These are affected by occasional bioturbation, slumping and winnowing. Stratified concretions or bands of iron, calcrete nodules and limestone fragments (boulder size) of the Naqb Formation are commonly encountered within the sediments of this sequence. Goethite (either in an earthy form or as pseudomorphs after framboidal pyrite) followed by *calcitized moss tufa*, gravity, stalactitic and isopacheous sparry calcite are the main cements of these sediments. The upper sequence of the lake sediments includes fining upward successions of limestone conglomerate, siltstone and calcareous mud together with skeletal debris of *Nummulites* and *Ostrea multicostata*. The framework fragments are cemented by drusy, blocky and granular calcite. Calcite algal tufa, in the form of branched thin threads encrusted by zoned sparry calcite are common. The sediments of this sequence indicate that they were derived from the carbonate rocks of the plateau, exposed at the time the topography was formed, through a prolonged period of weathering and transportation. They represent channel sediments laid down during torrential and fluvial stages.

It should be pointed out here that the main economic iron bands of this locality, which are recorded in the stratigraphic profiles of El Akkad and Issawi (1963), actually belong to the ironstones of the Bahariya Formation. In the course of the present work, special attention is given to the iron deposits confined to the described lake sediments. The megascopic geometric patterns of this iron type are illustrated and described in Figure8.Microscopically, the concentric layers of the concretions consist mainly of organic rich clays, detrital quartz grains and goethite, with less abundant hematite and pyrolusite. Goethite forms colloform growth banding and lamination with radial crystals growing on the growth surfaces. It may include patches of earthy hematite and quartz grains. Repeated concentric layers of colloform goethite and hematite are also observed. Veinlets of well crystallizing pyrolusite may cut across the colloform layers. Zoned sparry calcite fill the spaces between the concentric layers or the fractures cutting across the iron concretions and bands.

3.3. Filling Ore Type Of Large Scale Depression (El Gidida Mine)

El Gidida mine area is an oval-shaped depression, up to 15km^2, situated within the degraded karst cone hills of the Naqb Formation (Fig. 9). The central part of the depression is charactrized by a high relief, upon which conspicuous hills are scattered. The highest is Lyon's hill, up to 254,5 m above sea level and 42 m above the plateau surface of the high central area. These hills consist of highly silicified nummulitic limestone of the Naqb Formation. passing upward to a very hard crust of silcrete. The high central area and the associated relict hills are surrounded by the low wadi area, up to 198 m above sea level. Some hillocks of silcrete stand on the floor of the northern part of the depression. With exception of the conspicuous hills, the high central area and the wadi area are composed mainly of iron ore deposits, unconformably overlaying the Bahariya Formation (Fig. 10). The main structural elements of this area are the major anticline of El Gidida, affecting the Bahariya Formation, striking NE-SW and plunging to the NE and, normal major faults, trending NE-SW, N-S, and NW-SE. The NE-SW faults intersect the Naqb Formation along the western scarp of the depression and the ore body, with vertical displacements ranging between 3 and 25m.

The faults brought the Bahariya Formation against the ore of the wadi area and are dislocated by the NW-SE faults. These major faults may be related to the tectonic phase that prevailed at the end of the Oligocene, activating old structures (El Akkad and Issawi 1963; Basta and Amer 1969 a, b and Saad 1979). The ores and the associated overburden are commonly dissected by minor faults and fissures, striking NE-SW, NW-SE and E-W, with vertical displacements up to 2 m. The ore frequently exhibits slickensides and different generations of reworking.

El Gidida depression is obviously of structurally controlled karst origin, as it is situated along tbe anticlinal fold and appears to be formed by the denudation of the Eocene carbonates covering tbe crest and limbs of tbe anticline. This is clearly evidenced by tbe development of tbe residual hills in the high central area, which are similar in composition and form to those chara cterizing the surrounding karstic plateau, and the abundant distribution of corestones, collapse breccia fragments and weathering products within the ore layers. The morphology of the depression seems also to be controlled by tbe paleotopography of the Babariya Formation, as the bigb elevations of this formation are recorded in the central part of the depression, whereas it attains low relief in the wadi area (Fig. 10).

The sediments of the wadi area consist of two horizons, an upper, including tbe overburden, and a lower, consisting of the iron ore (Fig. 10). The contact between the two horizons is gradational and is marked by scour and fill structure. The overburden, up to 40 m thick, is made up of rhythmic layers of ferruginated and alunitized glauconitic clay and sand, alunite, yellow ocbers and separated or aggregated iron concretions. These concretions may form bands of variable thicknesses and often have a core of earthy hematite and limonite, surrounded by thin layers of colloform goethite, glauconite and alunite. These layered sediments are occasionally undulated and slumped or may sink deeply to or intertongue laterally with the sediments of the underlying ore horizon. The lower ore horizon, up to 38 m thick, is heterogeneous in character, exhibiting variation in composition, reflected by different colours, textures and degree of hardness. It consists of mixed stratified layers or lenses of variable thicknesses and lengths. The layers and lenses are generally of horizontal patterns, but sometimes slightly tilted, undulated and slumped. This ore horizon consists of the following: 1) varicoloured layers or lenses of ochers, showing gradual transitions to dark brown and massive hematitic ore, iron pisolites or crustified iron oxides. Small lenticular bodies of alunitized glauconitic sand or red stained kaolinite are commonly embedded within ochers (Pl. III, Fig. a); 2) connected or disconnected iron concretions, up to 30 cm in diameter, concordant with the bedding planes of the host sediments. Gradual coalescence of the concretions form symmetrical crustified bands and laminae; 3) cockade ore, consisting of successive rhythmic crusts of ocher, colloform goethite and hematite, developing around collapse breccia or rotten materials; 4) layers or lenses of ferruginated sandstone, siltstone and black shale, intercalated with earthy iron and manganese oxides. The binding materials of the sandstone and siltstone are oxidized minute pyrite crystals, pyrite framboids and calcite. The black shales also include abundant pyrite framboids and black organic remains; 5) layers or lenses of earthy manganese oxides or hydroxides, grading into manganese pisolites or concretions; 6) isolated lenticular masses of alunite or tripoli. The tripoli consists of powdery siliceous material with small fragments of silicified limestone, and 7) spherical *corestones* with silicified limestone and chert fragments embedded within the aforesaid sediments (Pl. III. Fig. b). They are usually arranged along several levels, conformable with the bedding planes of the layered host sediments. The corestones, up to 1.5 m in diameter, consist of highly silicified nummulitic limestone, similar to that of the karstic plateau, as a result of spheroidal weathering. The silicified limestone fragments are of boulder, cobble, pebble sizes, subangular to subrounded and mainly belong to the Naqb and Qaz-

zun formation (Pl. III, Fig. c). These mixed layers of the ore horizon may show convolute bedding, cut and fill, geopetal and load structures. The load structure is formed due to the gravititional sinking of the corestones and limestone and chert fragments into, and depressing the underlying sediments. The sediments of the ore horizon also include discrete pockets of *native* sulphur, oxidized algal filaments, plant rootlets and tissues. Veinlets of gypsum and halite commonly intersect the different layers or lenses of this horizon.

The ores of the high central area, up to 16 m in thickness, also are of heterogeneous character, as they consist mainly of stratified iron rich layers intercalated with lenses or layers of ochers, ferruginated sandstone, siltstone and kaolinitic clays (Fig. 10). Collapse breccia fragments, lenses of barite and oxidized organic remains (algal filaments and plant tissues) are enclosed within these layers. Salt crusts, up to several centimeters in thickness, are frequently deposited on the flat topped surface of the high central area. The iron rich layers exhibit the following megascopic and microscopic fabrics:

1) banded or laminated texture, consisting of successive deposition of hard colloform or earthy goethite with or without hematite and softer ocherous clayey materials. The bands or laminae range between 1 to 20 cm in thickness and may extend for several meters in length, with lateral gradation into ochers, iron concretions or crustified ore. They may include oxidized framboidal pyrite and siderite surrounded by colloform goethite or hematite; 2) crustified banded texture (Pl. III, Fig. d), forming symmetrical concentric overgrowths of colloform goethite, lepidocrocite, hematite and pyrolusite or consists of rhythmic crusts of earthy goethite and clayey sediments (Pl. III, Figs. e and f); 3) stratified isolated lenses of red earthy hematite set in yellow ochers; 4) convolute bedding and lamination, developed within undisturbed banded or laminated ore; 5) cockade structure, showing successive deposition of iron rich crusts around collapse breccia or ocherous sediments; 6) stratified arranged iron concretions, embedded within ochers; 7) pisolitic structure, and 8) comb structure, showing growth termination of needle shaped goethite, hematite, barite or calcite inside the remaining space left behind the iron crusts (Pl. III, Fig. g). The sandstones intercalated with the iron rich layers consist of subangular to subrounded quartz grains cemented by pyrite framboids, colloform goethite, barite and calcite (Pl. III, Fig. h). The quartz grains are highly shattered and cracked, indicating diurnal variation in temperature between day and night. The barite crystals are xenomorphic towards the framboids and goethite and show idiomorphic outlines against the calcite (Pl. III, Fig. i). Younger generation of goethite, filling cross cutting fractures is observed.

4. GENETIC DISCUSSIONS AND MODE OF ORE FORMATION

The landform evolution of the northeastern plateau of El Bahariya Oasis has proceeded from the youth and mature stages of paleokarst up to the peneplanation stage, under humid tropical paleoclimate. The karstification caused the Eocene carbonates to undergo slow chemical and physical transformations into soil. The various related duricrusts, so formed, indicate that the paleokarst has reached it's senile stage. The studied iron deposits are found to be mostly associated with karst features and soil products. They were accumulated on the tops of residual high lands or within excavated unconformity surface and karst depressions. The iron minerals together with the associated soily materials in all sites exhibit well pronounced depositional and diagenetic textures, corresponding to the typical sedimentary ore fabrics (Amstutz, 1963 and Schulz, 1976), and exactly identical to the textures of karst deposits and laterites (Bernard 1976; Padalino et al., 1976; Zuffardi 1976; El Aref and Amstutz 1983; Dzulynski and Sass Gustkiewicz 1985; El Aref et al. 1986; El Aref et al. 1987, Guilbert and Park 1986).

At Naqb Ghorabi, the occurrence, composition and character of the collapse breccia, together with the associated residual, biogenic and chemical products are good indications of karst ativity, that acted upon the Cretaceous-Eocene unconformity. The developed framboidal pyrite and siderite and their conformable relation with organic remains assure that biogenic processes were effective during the karstification and favourable reducing anaerobic conditions prevailed during the early lithification stage of the infilling karst sediments. The oxidation of the early formed framboids and siderite and the subsequent formation of colloform goethite, calcite, quartz and gypsum, suggest diagenetic crystallization differentiation from colloidal soil solution, controlled by changes in the physico-chemical conditions of soil environment and the concentration and solubility of the elements, as a result of oscillation of the water table and/or local biogenic processes.

The iron deposits of Ghorabi inselbergs form a conspicuous deep weathering or duricrust profile corresponding to the typical laterite profile. The difference between the recognized two horizons of this profile is related to the increase in the maturity of weathering and the geochemical behaviour and degree of mobility of the constituent elements during the pedogenesis. There is general agreement among many authors, that in tropical climate and under the effect of acidic organic compounds, all the mineral matter released near the surface are leached downword and eventually accumulate in the "B" horizon during illuviation processes and are partly transported to the lower "C" horizon (e.g. Bear 1967; Ollier 1975; Lelong et al. 1976; Smirnov 1976; Greensmith 1978; Bradshaw 1979; Birkeland 1984; Fitzpatrik 1986; and Zonn 1986). This can explain the concentration of the concretionary iron rich layers along the lower part of the upper indurated horizon. On the other hand, the concentration of ochers and the encrustation character of the iron oxides within the disintegrated lower horizon, together with the developed selvages of rottenstone indicate residual accumulation accompanied with seasonal change of the soil moisture, whereas the colloform character of goethite and hematite represents diagenetic crystallization from colloidal soil solution under favourable acidic to neutral conditions. The colloidal character of the soil solution is also evidenced by the development of isolated iron or manganese nodules and pisolites. Due to intensive rainfall, the lower soil layers are usually saturated with water and reducing environments prevail. This is clearly manifested by the abundant distribution of biogenic pyrite framboids and siderite. The rhythmic crustification character of the iron oxide or hydroxide and the oxidation of the early formed iron sulfide and carbonate reflect fluctuation between reducing and oxidizing conditions. Under the leaching regimes, solutions are highly diluted and Si is leached as easily as basis, while relatively immobile Fe and Al accumulate. On the other hand, under tropical but less intensively leaching conditions, solutions are not so highly diluted and Si is not released so easily. A part of it combines with Al to give Kaolinite and Fe continues to assume the hydroxide or oxide forms (Lelong 1976). Ca and Mg are released during the disolution of the carbonates and form compounds that are comparatively easily soluble in the zone of oxidation. They are therefore leached out of the weathering profile. Some of their compounds infiltrate in solution to the lower zones of mantle of waste, leading to redeposition of secondary carbonate cement. During the dry seasons, groundwater is drawn towards the surface, and $CaCO_3$ can precipitate in the form of calcrete nodules, stalactites or late cement. Due to very arid conditions soil waters move upward, causing precipitation of silica at the top of the weathering profile as cement or silcrete cover (quartzite or cherty layers). Also under the influence of a high local or regional water table, salts can accumulate. The rhythmic alternation between barite laminae and iron rich layers in the crustified iron type, the idiomorphic termination of the barite crystals towards the successive iron layers and their brecciation and recementation by iron minerals can be related to seasonal evapotranspiration and deposition under the influence of seasonal fluctuation of the water table.

The accumulation of ore deposits in the karst marginal plain of Nasser locality, their compostion, and synsedimentary fabrics argue for the role of weathering in their formation. Iron seems to be introduced by the weathering of the plateau or stripping and removal of the neighbouring mantles of waste, mainly as mechanical suspensions or in mobile form and was carried down into this basin, where deposition and diagenesis took place.

The iron oxides occurring within the lake sediments of El Harra area show typical stratiform geometric patterns, which imply syndepositional and diagenetic structures. The occurrence of botryoidal calcite in the cores of the concretions indicates rapid growth under vadose condition along the exposed surfaces of the sediments. The fracturing of the concretions suggest subaqueous shrinkage during drying out periods, followed by the crystallization of late diagenetic sparry calcite. Thus, the stratiform distribution of the iron concretions and bands represents marker horizons denoting air-water interfaces, interrupting the accumulation of the basin plain lake sediments.

In El Gidida mine area, the ore accumulated within large scale karst depression. A combination of surface and subsurface solution actions appear to be the main agents responsible for the excavation of this depression. Surface denudation is indicated by the presence of residual cone hills in the high central area and the abundant distribution of rounded boulders of silicifed limestone (corestones) within the ore of the wadi area. The occurrence of collapse breccia fragments, derived from the residual hills and embedded within the ore of the high central area proves subsurface solution action along the unconformity surface between the Eocene carbonates and the underlying Bahariya Formation. The composition and fabric of the ore minerals and associated weathering products argue for lateritic origin, during processes of residual deposition and diagenesis. The geochemical behaviour of the constituent elements during the pedogenesis is suggested to be responsible for the distribution of the different lithologic units throughout the depression. Al is only slightly mobile under common surface weathering conditions and it tends to accumulate as kaolinite or bauxite minerals. In the low pH ($pH < 4$), Al is more soluble than Fe, when the environment is oxidizing enough (Norton 1973). Therefore some dissociation of both elements is possible, Al being relatively leached in the superficial acid and well aerated layers of the soil profiles, before being redeposited in deeper horizons or further away laterally and is generally recognized as moving further than Fe (Duchaufour 1968). This may explain the concentration of alunite in the wadi area. The intercalations between the alunite and iron rich bands or lenses in the lower horizon of the wadi area indicate periodical changes in the Eh and pH conditions of the environment, which in turn reflects variation of the soil moisture. The concentration of Mn oxides or hydroxides in the wadi area is attributed to the geochemical behaviour of Mn during lateritization. The Mn behavior is controlled by the influence of the associated elements particularly Fe, or by its own chemical properties (Lelong et al. 1976). The Mn oxidation is much slower than Fe, when the redox potential exceeds 0.6 V in the presence of oxygen *and Mn can migrate* (Lelong et al. op. cit.). The mobility of the Mn in soils leads to a great tendency for it to move downwards from the relatively acidic upper parts of the soil profiles to lower parts, leaving behined Fe rich oxides and/or hydroxides (Sivapraksh 1980; Roy 1981 and Maynard 1983). The iron is solube as simple ferrous form or as organic sulphates and hydroxide complex in acid reducing water (Hem and Cropper 1959 and Osborn and Hem 1961). The accumulation of iron as ocher indicates residual concentration from suspension, whereas the formation of hard crusts or bands of colloform goethite and hematite represents diagenetic crystallization from colloidal or supersaturated pore soil solution. The development of silcrete cover and the silicification of the residual high hills can be related to the tendency of Si to migrate upwards through evapotranspiration processes and

redeposition under arid to semiarid regime. The formation of salts as surficial crusts or intercatlated pockets and stratified lenses of barite in the high central area reflect diminishing soil moisture due to oscillations in the water table level. Changes in soil moisture are also indicated by the shattering of quartz grains of the intercalated ferruginated sandstone lenses, and cementation of the shattered particles by pyrite framboids, colloform goethite barite and calcite. The late cementation of the lateritic materials by calcite reflects a decrease in the CO_2 partial pressure below the zone of rooting and a progressive increase in concentration of Ca^{++} and HCO_3^- in the soil solution as the water percolates downwards or is lost by evapotranspiration. The effect of biological processes during the pedeogenesis in this area is indicated by the formation of pyrite framboids and native sulfur and abundant distribution of plant remains and algal filaments throughout the ore body.

5. GENERAL CONCLUSIONS AND RECOMMENDATIONS

The present work summarises the results of field, megascopic and microscopic investigations carried out on the iron ore deposits of El Bahariya depression. The allover close correlation between karst landforms and features and the occurrences of the ore deposits elucidates the role of the paleotopgraphy, paleoclimate and pedogenic processes in the accumulation of these deposits. The different mineralized sites show similar geologic, geometric and mineralogical features, which led to their grouping as lateritic iron deposits. The existence of a series of syndepositional and syndiagenetic textures, observed in ore minerals and other karst products favours that they are a result of pedogenesis involoved during the senile stage of the karst. The changes in the soil moisture and physico-chemical conditions of the soil environment together with biogenic processes played an important role in leaching, transportation and redeposition of the iron minerals and associated materials. The lateritic deposits of El Bahariya can be correlated with the typical lateritic iron ores related to karstification and recorded in several localities in the world, e.g. Cuba and India (Guilbert and Park 1986), North Urals and West Orsk (Smirnov 1976) and Smirnov et al. 1983); Fluminimaggiore, Sardinia, Italy (Padalino et al. 1976); Brazil (Vann 1963); Philippines (Santos-Ynigo 1952); Queensland (Connah and Hubble 1960); North and Central Australia (Wright 1963 and Mabbutt 1965); South Africa (Maud 1968); Jamaica (Hill 1955); Nigeria (Dowling 1966) and Sudan (Faniran 1968 and Thomas 1974). Iron deposits of karst origin are also present in Gabal Abu Ghorban, Red Sea coastal zone, Egypt (El Araf et al. 1986).

In light of the present study and the forementioned discussion some main topics are suggested for further detailed investigations. The evolution of the karst landforms and the associated karst sediments should be systematically studied on regional scale, going from megascopic to microscopic features. This will enable us to determine the exact age of karstification and the related laterites and follow its evolution and modification in the subsequent paleoclimatic periods. It is also worthmentioning that the effect of karst processes and the formation of lateritic karst products have to be highly considered in the study and classification of the exposed carbonate units of the neighbouring regions with correlatable setting and conditions. Detailed geochemical studies using major and trace elements analyses of the lateritic profiles of each ore locality, are required to give more conclusive information about the mechanism of pedogenesis and the geochemical behaviour of elements involved during lateritization.

It is also recommended that the proposed genetic models of the iron deposits should be considered in further future exploration for other occurrences of ore in the surrounding areas,

especially those covered by the karstified Naqb Formation, using the landforms (high lands and depressions) and karst products as indicative guides. Thus the authors suggest that the most promissing area for iron ore exploration lies in the northeastern part of the Bahariya depression, covered by the karstified Naqb Formation, including the main scarp and extending east towards the Nile Valley.

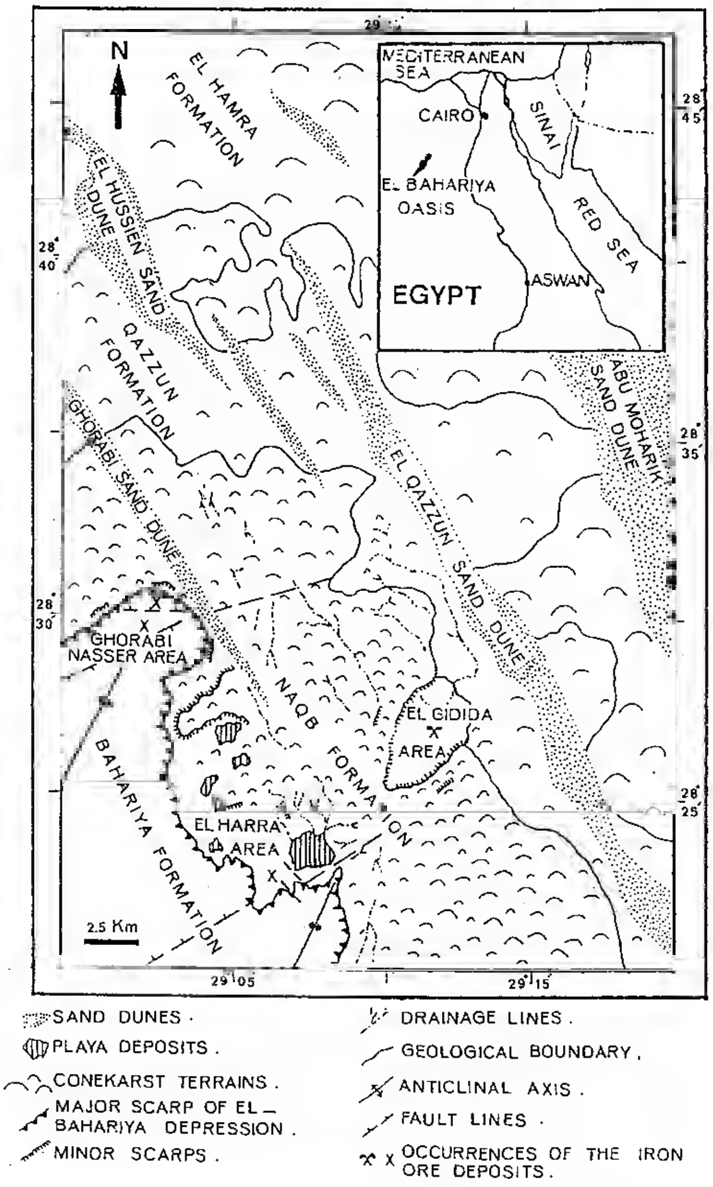

FIGURE 1. Simplified geological and geomorphological map of the northeastern plateau of El Bahariya Oasis.

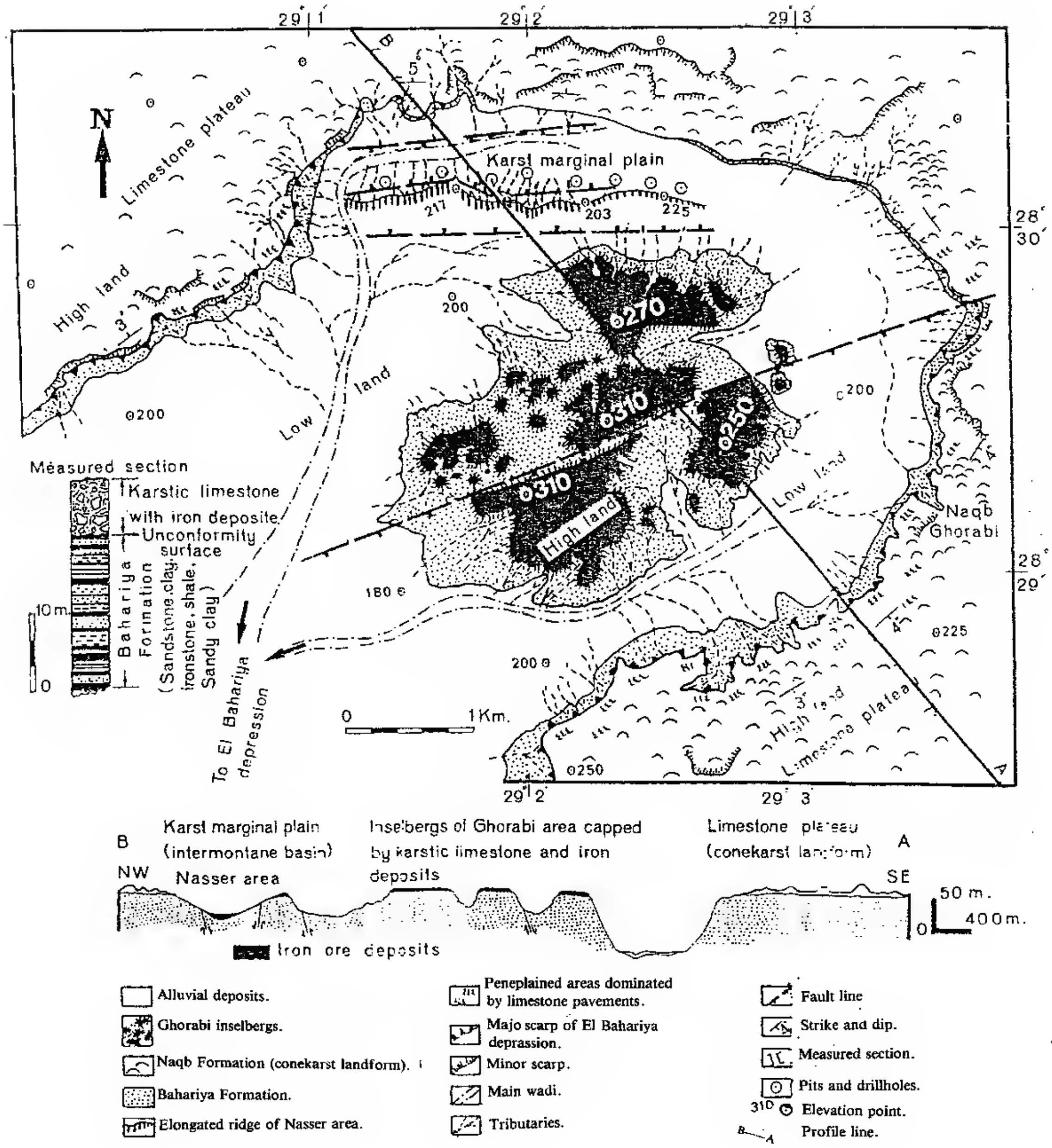

FIGURE 2. Geological and geomorphological map of Ghorabi Nasser area.

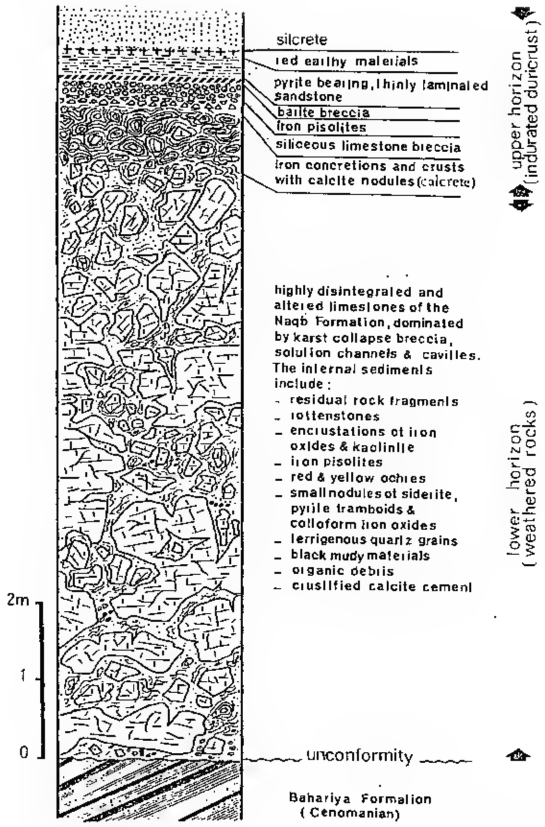

FIGURE 3. Sketchprofile of the karstic rocks of Ghorabi inselbergs.

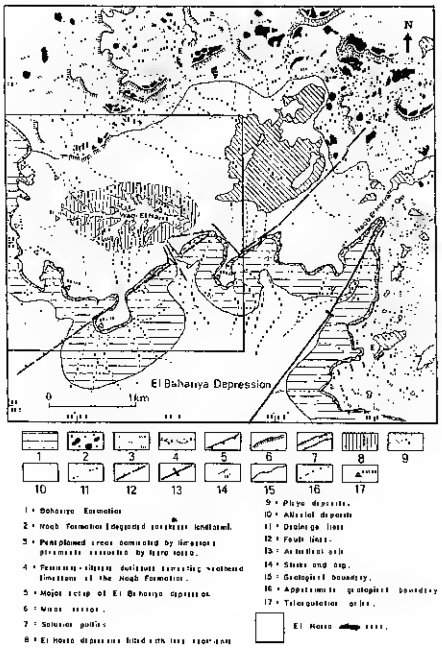

FIGURE 4. Geological and geomorphological map of El Harra locality.

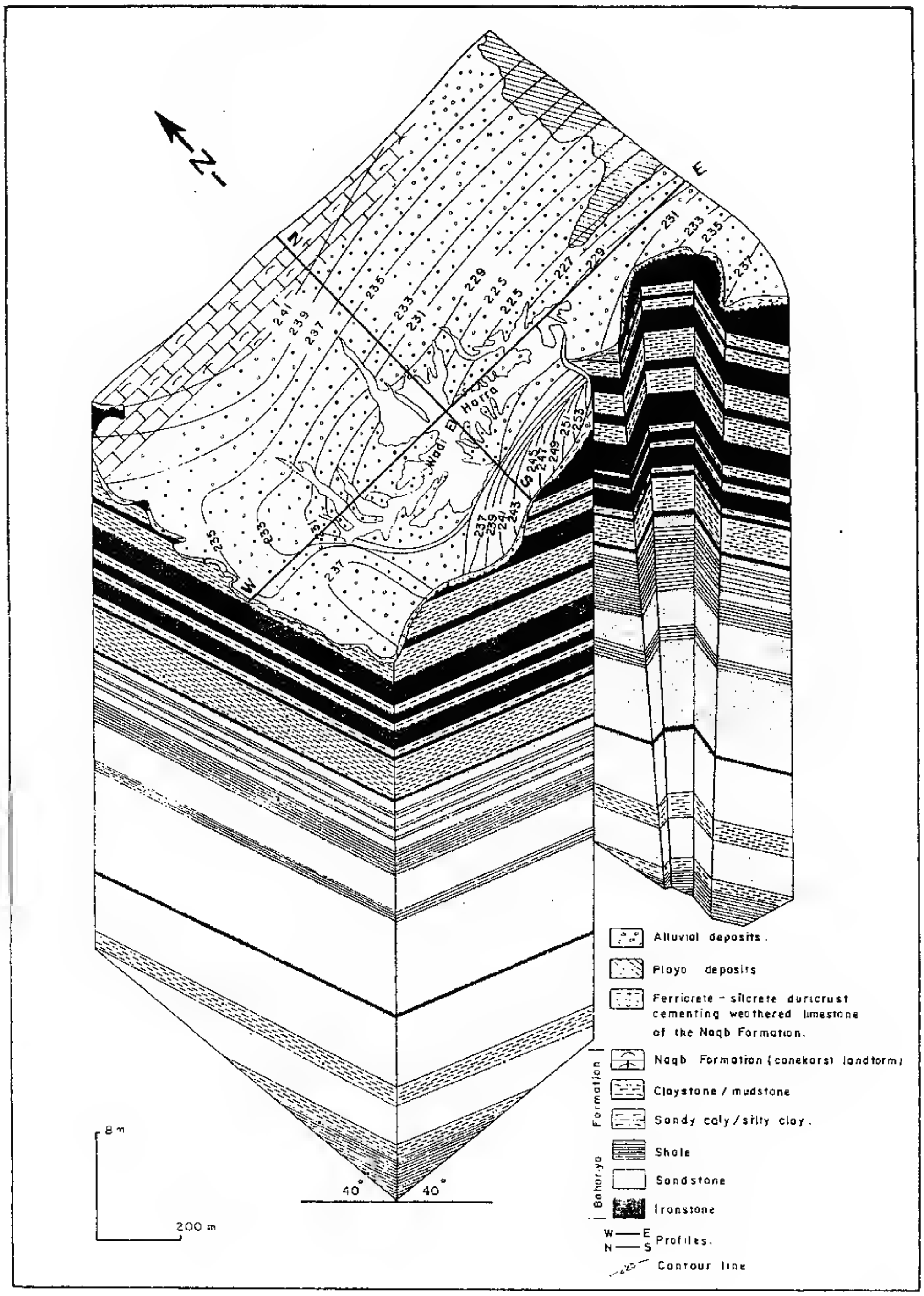

FIGURE 5. Isometric projection of El Harra deposit area.

FIGURE 6. Crossprofiles along the (N-S) and (E-W) directions of the isometric projection of El Harra area.

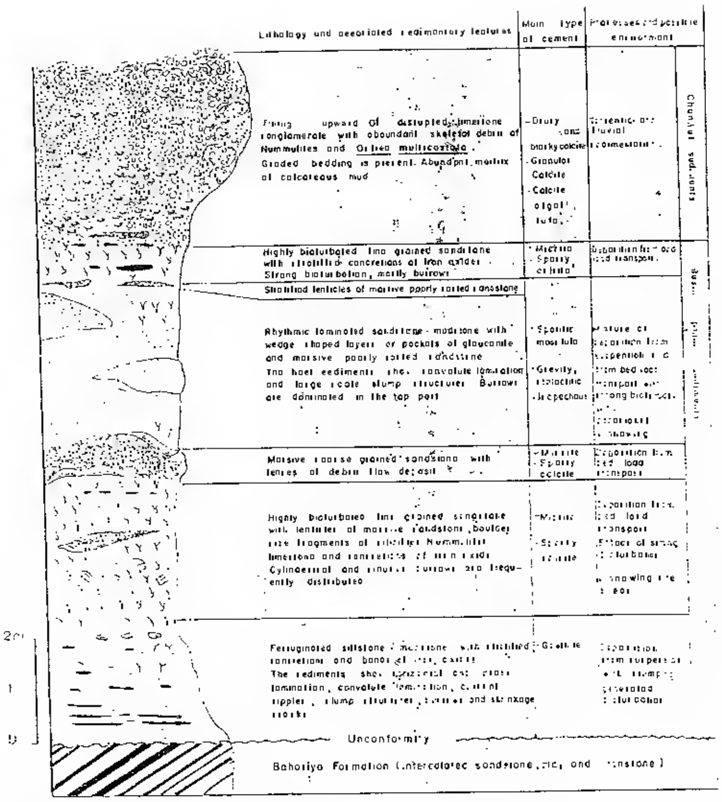

FIGURE 7. Composite lithostratigraphic profile of the lake sediments of El Harra deposit area and their environmental conditions.

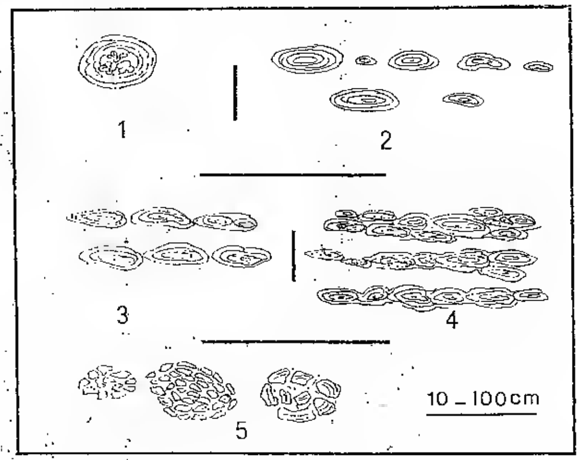

FIGURE 8. Geometric distribution patterns of the iron oxide, occurring within the lake sediments of El Harra deposit area. Type 1 = Isolated concretion with center of botryoidal calcite; type 2 = Stratified disconnected concretions or knots distributed along horizontal bedding planes; type 3 = Stratified connected concretions concordant with the horizonatal bedding planes; type 4 = Repeated stratified layers of coalsecent concretions, conformable with the horizontal bedding planes; type 5 = Fractured iron concretion of types 1 to 4. The fractures are filled with zoned sparry calcite.

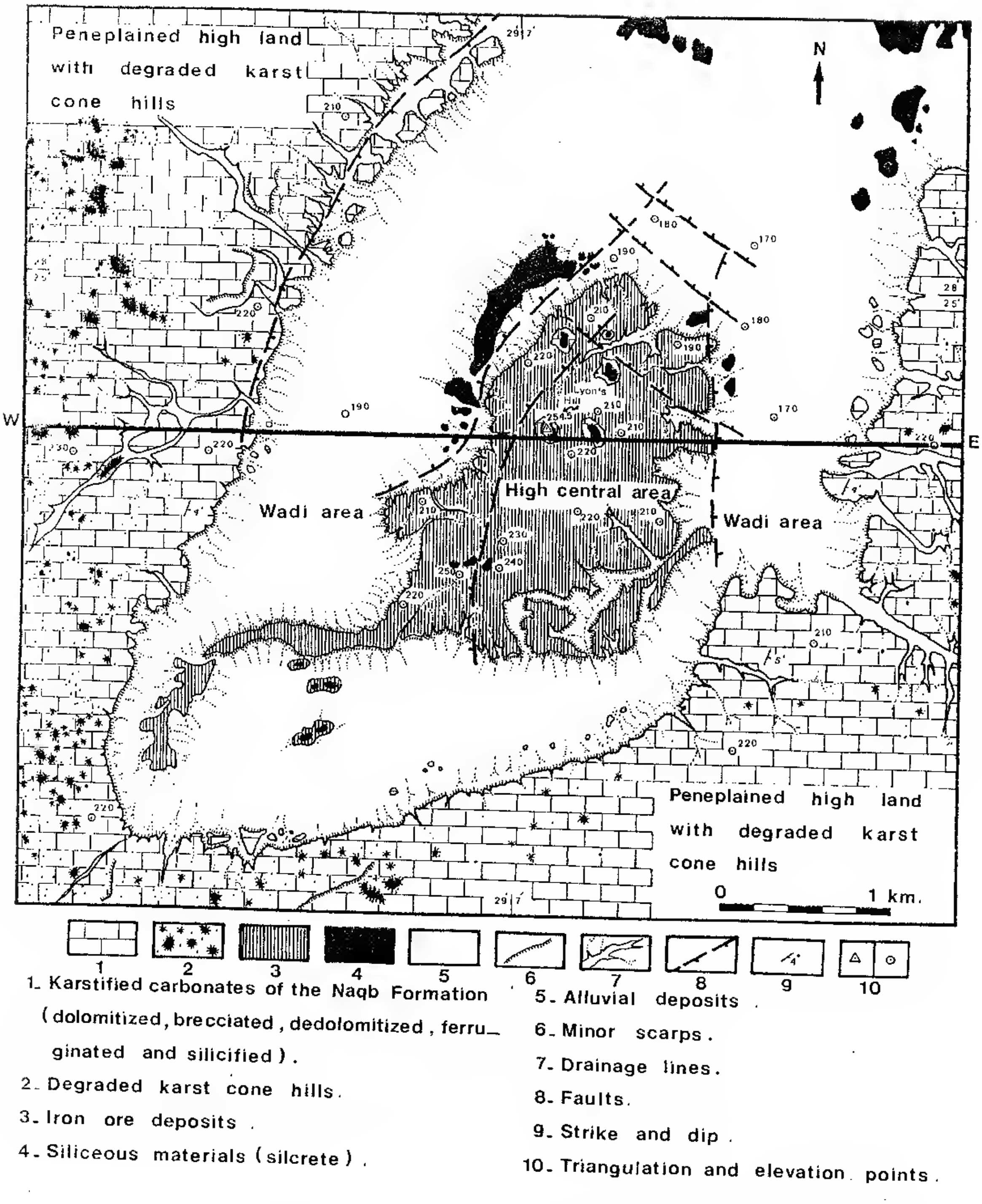

FIGURE 9. Geological and geomorphological map of El Gidida mine area (based on the geologic map of Basta and Amer, 1969 b, with modifications).

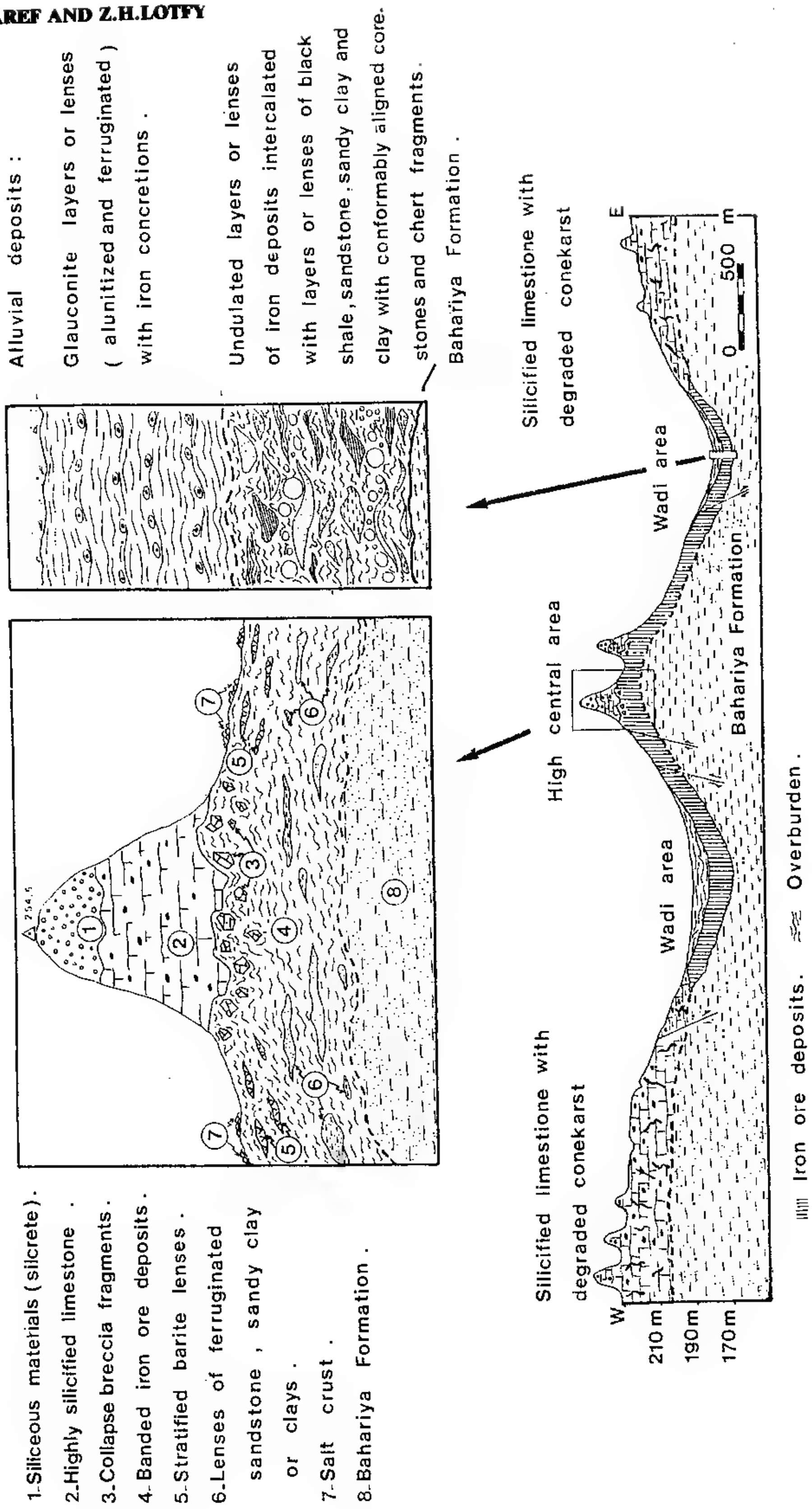

FIGURE 10. Exaggerated sketch profile of El Gidida mine area.

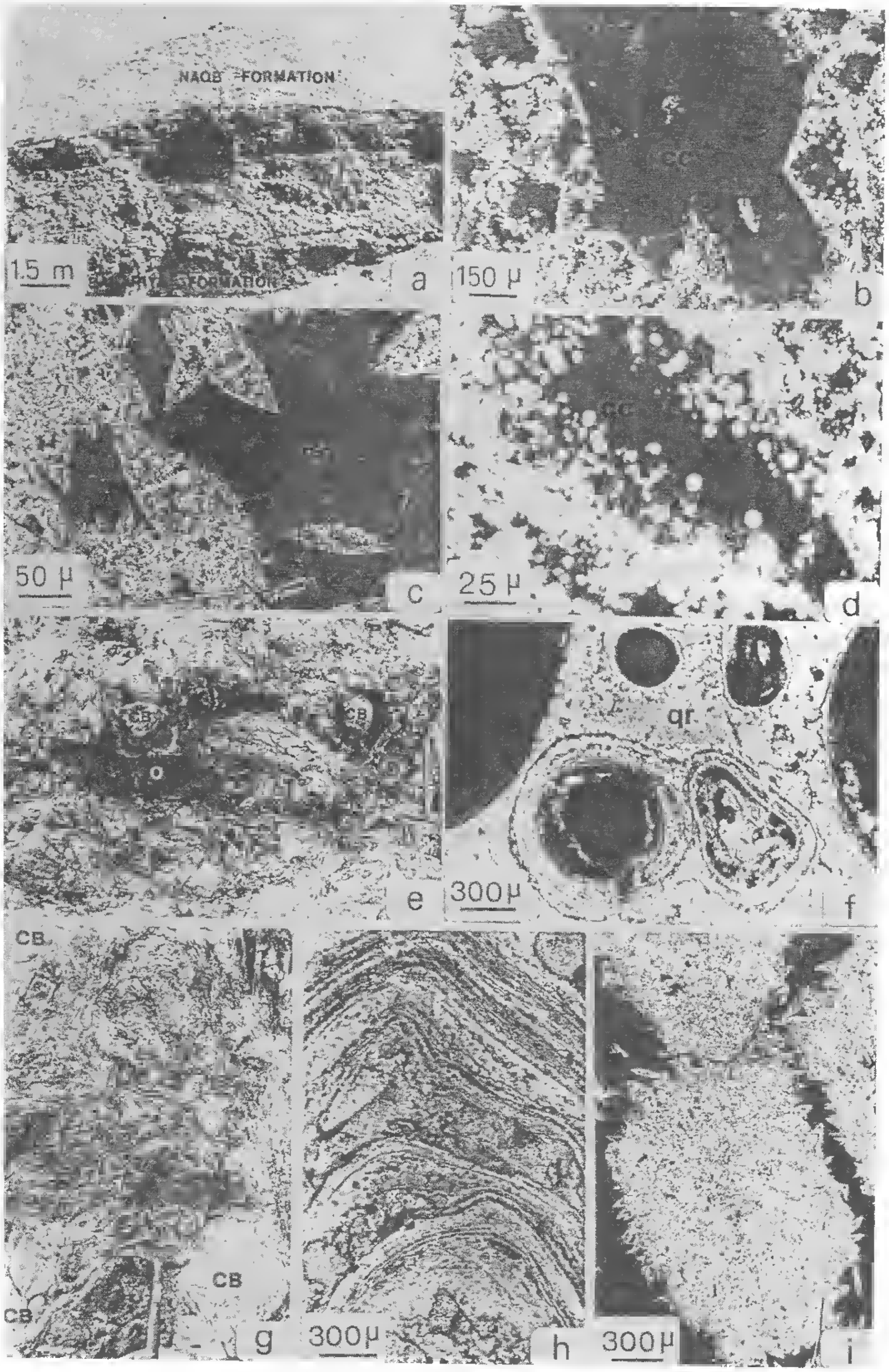
NAQB FORMATION
1.5 m
a
150 μ
CC
b
50 μ
c
CC
25 μ
d
CB
CB
O
e
qr
300μ
f
CB
CB
CB
g
300μ
h
300μ
i

PLATE I

Fig. a: Field view of a karst cone hill of the Naqb Formation at Naqb Ghorabi, showing the Cretaceous-Eocene unconformity. The unconformity surface is filled mostly with karst products.

Fig. b: Polished section (// N, air), of microcellular structure, replaced by oxidized siderite, minute pyrite crystals and pyrite framboids (white). The remaining spaces are filled with blocky calcite (cc), karst sediments of Naqb Ghorabi.

Fig. c and d: Two details of the same section as (b) showing the oxidized spindle-shaped siderite crystals (Fig. c) and pyrite framboids (Fig. d), cc = calcite.

Fig. e: Soltuion cavity of the lower horizon of the weathering profile of Ghorabi inselbergs. Notice, the development of rotten materials (RM) and ochers (O) along the internal walls of the cavity and around collapse breccia (B).

Fig. f: Polished section (// N, air) of iron pisolites, consisting of concentric laminae of goethite (white) and clayey materials (dark grey), qr = mosaic quartz, karst sediments of Ghorabi inselbergs.

Fig. g: A close up view, showing collapse breccia fragments (CB) cemented by crustified iron oxides. Oxidized tissues of plant remains (arrows) are encountered within the cement. Intrafragmental small cavities are filled with concentric crustified iron oxides (upper left corner of the photo), lower horizon of the weathering profile of Gabal Ghorabi.

Fig. h: Polished section (// N, air) of stromatactis algal filaments, lower horizon of the weathering profile of Gabal Ghorabi.

Fig. i: Polished section (// N, air) of small scale nodules of oxidized siderite crystals cemented by blocky calcite (cc), the lower horizon of the weathering profile of Gabal Ghorabi.

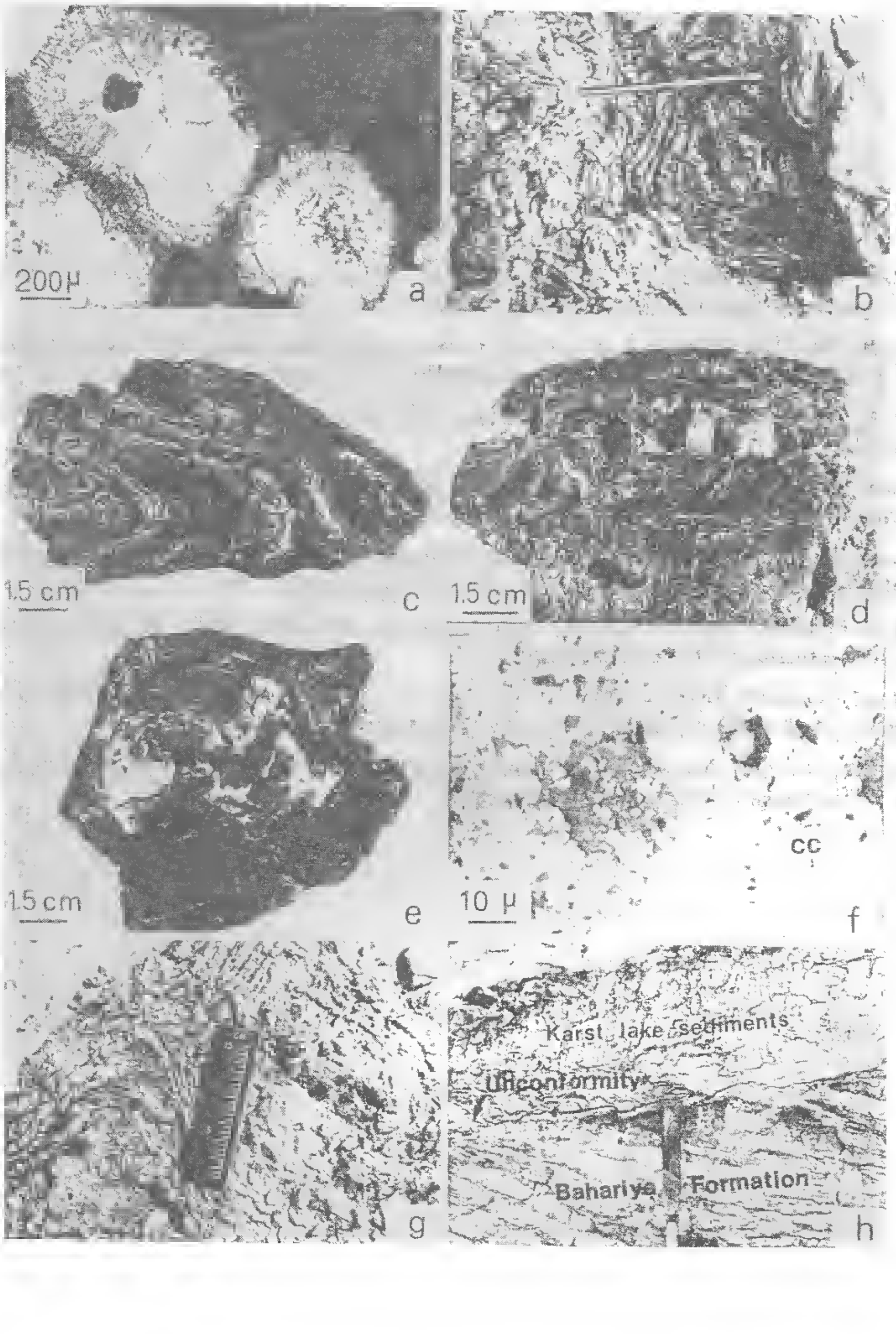
200μ
a
b
1.5 cm
c
1.5 cm
d
1.5 cm
e
cc
10 μ
f
g
Karst lake sediments
Unconformity
Bahariya Formation
h

PLATE II

Fig. a: Polished section (// N, air) of nodules of colloform goethite (white) cemented by quartz (qr), the lower horizon of the weathering profile of Gabal Ghorabi.

Fig. b: Crustified rhythmic layers of iron oxides and clays deposited around limestone fragment (RF), forming cockade structure, the lower horizon of the weathering profile of Gabal Ghorabi.

Fig. c: Crustified banded ore of the indurated upper horizon of the weathering profile, of Gabal Ghorabi.

Fig. d: Stalactiform calcite (white) growing in the empty spaces between iron crusts, the upper horizon of the weathering profile of Ghorabi inselbergs.

Fig. e: Nodules of calcrete (white) cementing fragments of crustified ore and iron concretion, the upper horizon of the weathering profile of Ghorabi inselbergs.

Fig. f: Polished section (// N, air) of pyrite framboids cemented by calcite (cc), the upper horizon of the weathering profile of Gabal Ghorabi.

Fig. g: Concentric rhythmic layers of ocherous materials (light grey) and indurated colloform goethite (dark grey), deposited around altered limestone fragments, Nasser locality.

Fig. h: A close up view showing the angular unconformity between the Bahariya Formation and the overlaying lake sediments. El Harra locality.

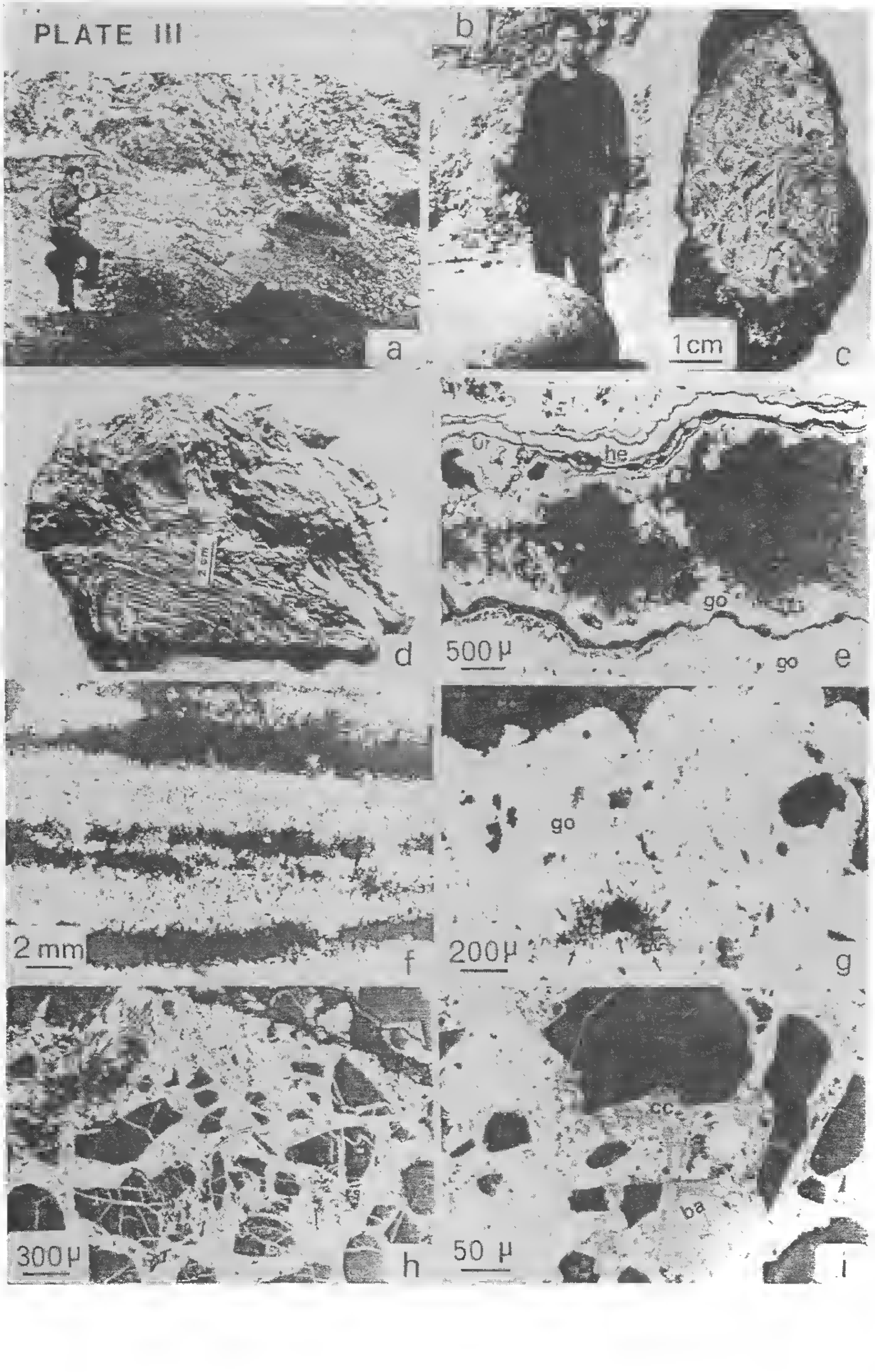
PLATE III
a
b
c
1 cm
d
e
he
go
go
500 μ
f
2 mm
g
go
200 μ
h
300 μ
i
cc
ba
50 μ

PLATE III

Fig. a: Field view showing lenticular layers of alunite (white) encountered within the ore of the wadi area, El Gidida mine.

Fig. b: Well rounded corestone, extracted from the iron ores of the wadi area, El Gidida mine.

Fig. c: Handspecimen of collapse breccia, consisting of silicified nummulitic limestone and extracted form the ore of the high central area, El Gidida mine.

Fig. d: Handspecimen of the crustified banded ore of the high central area, El Gidida mine.

Fig. e: Polished section (// N, air), showing rhythmic crustification of colloform goethite (go) and hematite (he) with organic rich layers (black), cc = calcite, crustified ore of the high central area, El Gidida mine.

Fig. f: Polished section (// N, air), showing rhythmic bands of earthy goethite (white) and clays (grey), crustified banded ore of the high central area, El Gidida mine

Fig. g: Polished section (// N, air), showing needle shaped hematite crystals (arrows) growing in vuggy structure within colloform goethite (go), cc = calcite, crustified ore of the high central area, El Gidida mine.

Fig. h: Polished section (// N, air) of the ferruginated sandstone of the high central area of El Gidida mine. Notice, the shattering of the quartz grains (dark grey).

Fig. i: Detail of figure h. The cement consists of oxidized framboidal pyrite (white spheres), colloform goethite (white patches), barite (ba), and calcite (cc). Veinlet of new generation of goethite is shown in the left part of the photo.

REFERENCES

Agthe, C. 1985, Die Genese der Eisenerzc von Djebel El Ghorabi, Djebel El Harra, El-Gedida und der Eisenkrusten von El Heiz, Bahariya Oasis, Western Desert, Egypten. Berl. Geowiss. Abh, 68, 85 P.

Amer, H.I., 1968, Mineralogical and geological studies on the iron ore deposits of El Gidida area, Bahariya Oases, Western Desert, Egypt: M. Sc. Thesis, Fac. Sci., Cairo Univ., 207 p.

--------------, 1973, Gological and mineralogical studies on the Bahariya Oasis and their iron ore deposit, Western Desert, Egypt: Ph.D. Thesis, Fac. Sci., Cairo Unive., 338 p.

Amstutz, G.C., 1963, Bemerkungen zur Genese von Kongruenten Blei-Zink-Lagerstatten in Sedimenten.: Ber. Geol. Ges., Berlin, Sh. 1, 31-42.

Attia, M.I., 1950, The geology of the iron ore deposits of Egypt: 18th Intern. Geol. Congr., London. 13, 6-13.

Awad, W.K.; Riad, S. and Refai, E., 1980, The applicability of complex geophysical methods as indirect tool for iron ore exploration at Bahariya Oasis area, Western Desert. Egypt: Ann. G.S.E., X, 147-168.

Ball, J. and Beadnell, H.J.L., 1903, Bahariya Oasis, its topography and geology Egypt. G.S.E., Cairo, 84 p.

Basta, E.Z., and Amer, H.I. (1969, a), Geological and petrographic studies on El Gidida area, Bahariya Oasis, U.A.R.: Bull. Fac. Sci. Cairo Univ., 43, 189-215.

--------------------------------, (1969, b), El Gidida iron ores and their origin, Bahariya Oases, Western Desert: U.A.R. Econ. Geol., 64, 424-444.

--------------------------------, (1969, c), Mineralogical investigations on the iron ore deposit of El Gidida area, Bahariya Oases, U.A.R: Bull. Fac. Sci., Cairo Univ., 43, 237-269.

--------------------------------, (1969, d), A geochemical study on the iron ore deposit of El Gidida area, Bahariya Oases, U.A.R: Bull. Fac. Sci., Cairo Univ., 43, 237-269.

Bear, F.E., 1967, Chemistry of the soil: second edition. American Chemical Society Monograph Series. Reinhold Publishing Corporation. London. 515 p.

Bernard. A.J., 1976, Metallogenic processes of intra-karstic sedimentation. In: Amstutz, G.C. and Bernard, A.J. (eds.), Ores in sediments. Springer, Berlin-Hidelberg, 43-57.

Birkeland, P.W., 1984, Soils and geomorphology: Oxford University Press, New York, Oxford. 372 p.

Bradshaw, M.J. 1979, Earth, the living planet: The English Language Book Society and Hodder, Stoughton. 302 p.

Connah, T.H. and Hubble, G.D., 1960, Laterites. In: Hill, D. and Denmead, A.K. (eds.), The geology of Queensland, Melbourne, 373-386.

De Voto, R.H., 1987, Late Mississippian paleokarst and related mineral deposits, Leadville Formation, Central Colorade In: James, N.P. and Choquette (eds), Paleokarst. Springer Verlage, New York I, 278-305.

Dowling, J.W.F, 1966, The mode of occurrence of laterites in N. Nigeria and their appearance in aerial photography: Eng. Geol., 1, 3, 221-33,

Duchaufour, P., 1968, L'evolution des Sols. Essai sur la Dynamique des Profils. Masson, Paris, 94 p.

Dzuiynski, S. and Sass Gustkiewicz, M. (1985), Hydrothermal karst phennomena as a factor in the formation of Missisippi Valley-type deposits. In Wolf, K.W. (ed.), Handbook of strata-bound and stratiform ore deposits, Amsterdam Oxford-New York, V1, 13, 391-439.

El Akkad, S. and Issawi, B., 1963, Geology and iron ore deposits of the Bahariya Oasis: G.S.E., Cairo, 18, 301 p.

El Aref, M.M. and Amstuz, G.c., 1983, Lead-zinc deposits along the Red Sea coast of Egypt, new observations and genetic models on the occurrences of Um Gheig, Wizer, Essel and Zug El Bohar. Monograph Series on Mineral Deposits: Gebruder Borntraeger, Berlin, Stuttgart, 21, 103, p.

-------------------, Awadalah, F. and Ahmed, S. 1986, Karst landform development and related sediments in the Miocene rockes of the Red Sea coastal zone, Egypt: geologische Rundschau, 75/3, 781-790.

-------------------, Abou Khadrah, A.M. and Lotfy, Z.H., 1987, Karst topography and karstification processes in the Eocene limestone plateau of El Bahariya Oasis, Western Desert, Egypt: Z. Geomorph. N.F., 31, 1, 45-64.

El Sharkawi. M.A.; Higazi, M.M. and Khalil, M.A., 1984, Three genetic types of iron ore at El Gidia mine, Western Deset, Egypt. Twenty Second Anual Meetin, Geol. Soc. Egypt, (abstract).

-------------------, and Khalil, M.A., 1977, Glauconite, a possible source of iron for El Gidida iron ore deposits, Bahariya Oases, Egypt: J. Geol., 21, 1, 109-116.

El Shazly, E.M., 1959, Notes on the mining map of Egypt. Reports, 20th Intern. Geol. Cong., Mexico (1956), XIII. Assoc African Geol. Surv., 423-437.

-------------------, 1962, The result of drilling in the iron ore deposit of Gebel Ghorabi, Bahariya Oases, Western Desert, and report on the mineralogy of the low grade iron ores of El Heiz area, Bahariya Oases, Western Desert: G.S.E., Cairo, 50 p.

Faniran, A., 1968, A deeply-weathered surface and its destruction, Ph. D. Thessis, Univ. of Sydney, N.S.W. From: Faniran, A. and Jeje, L.K. (1983). Humid tropical geomorphology: Longman Group Ltd., London. Lagos, New York, 414 p.

Fitzpatrik, E.A., 1986, Soils, their formation, classification and distribution. English Language Book Society, Longman. 353 p.

Gheith, M.A., 1955, Classification and review of Egyptian iron ore deposits. Symposium appl. geol. in the Near-East: UNESCO, Ankara, 106-113.

---------------, 1959, Mineralogy, thermal analysis and origin of the Bahariya iron ores of Egypt 20th Intern. Geol. Cong., Mexico.

Greensmith, J.T., 1978, Petrology of the sedimentary rocks: sixth edition. George Allen and Unwin/Thomas Hurby, London, Boston, Sydney, 241 p.

Guilbert, J.M. and Park, C.F., 1986, The geology of ore deposits: W.H. Freeman and Company, New York, 985 p.

Hem, J. D. and Cropper. W.H., 1959, Survey of ferrous-ferric chemical equilibria and redox potentials: USGS Water Sup., Pap. 1459-A, 1-31.

Hill, V.G., 1955, The mineralogy and genesis of the bauxite deposits of Jamaica: B.W.I., Amer. Miner., 40, 676-89.

Hume, W.F., 1909, The distribution of iron ores in Egypt: Egypt Surv. Dept., Cairo, 36, 225-228.

Jakcus, L., 1977, Morphogenesis of karst regions. Variants of karst evolution: Adam Hilger Bristol. 284 p.

Kamel, O.A., 1971, The Bahariya iron ores, their mineralogy and origin: Annals G.S.E., 1, 117-134.

Khalil, M. A., 1984, Chemical and mineralogical variations of iron ore mine in El Gidida area, Bahariya Oases, Western Desert, Egypt: M. Sc. Thesis, Fac. Sci., Al-Azhar University, Cairo, 99p.

Lelong, F.; Tardy, Y., Grandin, G., Trescases, J.J. and Boulange, B. 1976, Pedogenesis, chemical weathering and processes of formation of some supergene ore deposits. In Wolf, K.H. (ed.), Handbook of strata-bound and stratiform ore deposits, 3, 93-173.

Lotfy, Z.H., 1988, Geological, sedimentological and mineralogical study of the northeastern plateau, Bahariya Oasis, Egypt: Ph. D. Thesis, Fac. Sci., Cairo Univ., 330 p.

Mabbutt, J.A. 1965, The weathered land surface of Australia: Z. fur Geomorph., 82-114.

Maud, R.R., 1968, Further observations on the laterites of coastal Natal, S. Africa, Trans. 9th Intern. Congress of Soil Sci., Adelaide, 4, 151-8.

Maynard, J.B., 1983, Geochemistry of sedimentary ore deposits: Springer-Verlag, New York, 305 p.

Nakhla, F.M., 1961, The iron ore deposits of El Bahariya Oases, Egypt: Econ. Geol., 56, 1103-1111.

Neev, D., 1975, Tectonic evolution of the Middle East and the Levantine Basin (easternmost Mediterranean): Geology, 3, 683-686.

----------, 1977, The Pelusium Line, a major transcontinental shear: Tectonophyscics, 38, T1-T8.

Norton, S.A., 1973, Laterite and bauxite formation. Econ. Geol. 68, 353-567.

Ollier, C.D., 1975, Weathering. Edited by Clayton, K.M.: English Language. Book Society and London Group Ltd., 304 p.

Osborn. E.T. and Hem, J.D. 1961, Microbiologic factors in the solution and transport of iron: USGS Water Sup., Pap. 1459-H, 213-235.

Osman, H., 1969, Geological studies of the iron deposits of Bahariya Oasis: M.Sc. Thesis, Assiut Univ., Assiut, 107 p.

Padalino, G.; Pretti, S., Tamburaini. D., Tocco, S., Uras, I., Violo, M. and Zuffardi, P., 1976, Ore deposition in Karst Formation with examples form Sardinai, In: Amstutz, G.C. and Bernard, A.J. (eds.), Ores in sediments. Springer, Berlin, Heidelberg, 209-221.

Roy, S., 1981, Manganese deposits: Academic Press, London, 548 p.

Saad, A.N.A., 1979, Geology of east of Bahariya Oasis, Western Desert, Egypt: Ph. D. Thesis, Fac. Sci., El-Azhar Univ., A.R.E. 346 p.

Said, R., 1962, The geology of Egypt: Elsevier Pub. Co., Amesterdam. New York, 377 p.

----------, and Issawi, B., 1964, Geology of northern plateau, Bahariya Oasis, Egypt. G.S.E.Egypt,

Cairo, 29, 41 p.

Santos-Ynigo, L., 1952, The geology of iron ore deposits of the Philippines: Symposium gisements de terre du monde, Alger, tome 1.

Schulz, O., 1976, Typical and nontypical sedimentary ore fabrics. In: Wolf K.H. (ed.), Handbook of strata-bound and stratiform ore deposits, 3, 295-338.

Sivapraksh, G., 1980, Mineralogy of manganese deposits of Kodura and Garbham, Andhra, Pradesh, India. Econ. Geol., 75, 1083-1104.

Smirnov, V.I., 1976, Geology of mineral deposits, (Translated by H.C. Creighton). Mir Publishers, Moscow, 520 p.

--------------, Ginzbura, A.I., Grigoriev, V.M. and Yakovlev, G.F., 1983, Studies of mineral deposits (Translated by A.A. Beus): Mir Publishers, Moscow, 288 p.

Thomas, M.F., 1974, Tropical Geomorphology, a study of weathering and landform development in warm climates: Macmillan, London.

Tosson, S. and Saad, N.A., 1974, Genetic studies of El Bahariya iron ore deposits, Western Desert, Egypt.: N. Jb. Miner. Abh., Stuttgart, 131 (3), 293-317.

Vann, J.H., 1963, Development processes in laterite terrain in Amapa: Geog. Rev., 53, 3, 406-17.

Wright, R.L., 1963, Deep weathering and erosion surfaces in the Daly River Basin, Northern Territory: J. Geol. Soc. Aust., 10, 151-63.

Zonn, S.V., 1986, Tropical and subtropical soil science: Mir Pub., Moscow, 442 p.

Zuffardi, P., 1976, Karst and economic mineral deposits. In: Wolf, K. (ed.), Handbook of strata-bound and stratiform ore deposits: Elsevier, Amsterdam, 3, 175-212.

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